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Predicting Seed Yield of Birdsfoot Trefoil Clones

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Predicting Seed Yield of Birdsfoot Trefoil Clones

COMMERCIAL SEED PRODUCTION of birdsfoot trefoil (*Lotus corniculatus* L.) has been mainly in the northern United States and southern Canada. The more winter-hardy varieties of the semiprostrate pasture type and semierect hay type have maintained satisfactory stands and seed yields in the Lake Champlain region of New York and Vermont, in the Great Lakes region of southern Ontario and northern Wisconsin, and in Minnesota, North Dakota, Iowa, and Montana. Both these varieties and those that are less-winter-hardy have been reasonably satisfactory for seed production in the Willamette Valley and southwestward in Oregon.

Seed of new varieties intended for forage production in the North Central Region probably will be grown in one or more of these areas. Hence, breeders would like to know if seed potential measured at one geographic location where plant selection is practiced, will usefully predict actual seed yield at distant locations of commercial production. If so, then evaluation of the clones at breeding stations could be improved and simplified. Cooperators were available for such investigations in Oregon, North Dakota, Minnesota, Iowa, Missouri, and Illinois. Experiments were conducted at these locations to determine: (a) whether associations exist between seed production potential and morphological and physiological plant characteristics, and (b) if such associations are great enough to aid in selecting plants with both desirable forage and seed production potential.

REVIEW OF LITERATURE

This study was patterned after a more comprehensive study of alfalfa by Rumbaugh *et al.* (*17*).[1] Since seed production of new alfalfa varieties is concentrated in dry, irrigated sections of the Far West, the Rumbaugh study attempted to predict seed yields in the West from morphological and physiological plant characteristics in the North Central Region.

In the Rumbaugh study, seed yields of 29 clones measured for two years in California and Idaho were the dependent variables, and plant characteristics in six north central states were the independent variables used to construct multiple regression prediction equations. Equations were first computed with all variables, then variables of lesser significance were dropped until the coefficient R dropped below .80. The remaining variables were considered to be of the greatest predictive value in a breeding program. Also reported were simple correlations between the eastern variables and the western seed yields, as well as intercorrelations of seed yield among four sets of western data.

Results of the Rumbaugh study showed moderately strong associations between several north central variables and western seed yields. However, no single independent north central variable was associated with seed yields enough to satisfactorily predict western seed yield potential. In simple correlations of eastern first- and second-year traits with western first- and second-year yield, characters shifted in relative importance from test to test. Positive intercorrelations of western seed yields were .58 to .83. In multiple correlations using all traits for each state in each year, r ranged from .53 to .94. In backward stepwise regression to a terminal point of r = .80, the most efficient predictions were obtained from the Nebraska data; that is, the fewest variables were required in terminal equations. On the average, 5 variables were required per equation, and the range was from 2 to 6 variables across eight terminal sets. However, the variables (or traits) within the sets were not consistent, and a total of 15 variables were required for the eight sets. The report failed to include seed size and character intercorrelations at each station, and both are needed to round out the conclusions.

Several other investigators have studied various problems in predicting seed potential of alfalfa clones. Dade *et al.* (*5*) found that seed yields in Kentucky did not satisfactorily predict seed yields in Washington, but that first- and second-year rankings of seed yield in Washington agreed closely (r = .86). Taylor (*21*) reported pods per raceme and racemes per stem to be important components of seed yield in alfalfa. A combination of these components predicted potential yield, but potential yield was not associated with harvested yield. Liang and Riedl (*12*) found plant height, seed size, fertility, and number of tillers to be positively correlated with seed yield in alfalfa; and Pedersen and Nye

[1] Italicized numbers in parentheses refer to the literature cited on page 16.

(*16*) found component factors to be compensatory in seed production. These various findings suggest the need for further study of the complex relationships between plant traits and seed production in alfalfa.

The results of the alfalfa studies also raise questions about the biological and statistical nature of the search for terminal sets. For instance, could a set or sets of characters be found in birdsfoot trefoil clones that would predict seed yield? Would these characters prove reliable predictors year after year? Would the number of characters be low enough to make the practice economically practical? Accordingly, our study sought to determine in the potential seed-producing areas whether a reliable system of seed production could be developed through selecting and breeding plants with desirable characters.

The literature reveals no comprehensive investigation of birdsfoot trefoil comparable to the study of alfalfa by Rumbaugh *et al.* (*17*). However, several reports deal with the relationships of seed yield with other plant characters and with genetic variation.

Using 26 widely divergent clones, Bresciana (*3*) studied the value of seven component characters for predicting seed potential. According to simple correlation coefficients and standardized partial regression coefficients, seed yields were highly predictable by use of these components. The number of umbels per plant and number of pods per umbel, for instance, were equally influential and together accounted for 60 percent of the variation in yield. Prediction based on just these two variables was adequate for computing theoretical yields that agreed closely with actual yields, and allowed simple, reliable, and early estimation of seed yields from single, spaced plants.

Two studies found that genetic characteristics were important in predicting seed yield. Albrechtsen *et al.* (*1*) used path coefficient analysis of correlation, as proposed by Li (*11*), to study the interrelationships between genetic and phenotypic characteristics, and seed production. Broad sense heritability for seed yield was high, and suggested that seed yields could be raised by appropriate plant selection to 93 percent above the population mean. Similarly, Peacock and Wilsie (*15*) found by path coefficient analysis that genetic effects outweighed environmental effects in progeny variation, indicating a potential for improvement of seed yield by selection and intermating of superior phenotypes.

However, the results of an experiment conducted by Garrison (*6*) indicate that clones do interact with environments, causing unequal crossing as well as unequal genetic proportionment in the formation of synthetics. His experiment to determine relative seed production of clones at different geographic and physiographic locations showed differential behavior of clones between locations, and to a lesser extent between years. The bias in the formation of synthetics could be compounded by the bias possible from selfing and sibbing as implied in the results of Bansal (*2*). His findings indicate that compatibility-related factors need to be considered in studies of seed potential in populations having self-fertility or cross-fertility problems.

Results of these birdsfoot trefoil studies, like the results with alfalfa, indicate we have an incompletely defined picture of the complex relationships between plant traits and seed production. We need to refine and standardize techniques of measurement and analysis of seed yield, its components, and associated variables. For example, a single, momentary count or rating of open florets does not accurately measure indeterminate cumulative flower production. The tendency of trefoil to produce cyclic flushes of new growth and new bloom from new buds of stem axils or crowns or both, depending on the variety, is another complication in assessing seed potentials.

TECHNICAL DESCRIPTION OF BIRDSFOOT TREFOIL

A considerable store of information about the life cycle of birdsfoot trefoil relates to seed production. We have constructed the following summary of pertinent information from reviews such as Henson and Schoth (*9*), Seaney and Henson (*20*), McDonald (*13*), and Hughes *et al.* (*10*); and from special reports such as Giles (*7*), Miri and Bubar (*14*), Bansal (*2*), Seaney (*18, 19*), and Hawk (*8*). We have also drawn information from other selected sources, including published research, symposia, work conferences, surveys, personal communications, and the practical experience of researchers and seed producers.

Lotus corniculatus L. is a tetraploid (2N = 24), probably an allotetraploid, and shows mostly bivalent pairing and tetrasomic inheritance. In the field it is largely cross-pollinated, being highly cross-compatible and largely self-incompatible. Although populations with higher self-fertility can be developed, normally over 90 percent of the plants show little or no self-fertility, and the rest produce 0.5 or more seeds per floret pollinated, but rarely as many as 5.0 or more seeds. Cross-pollinated plants give 5.0 to 15.0 seeds per floret. Stigmas require scarification by bees or by mechanical means; but once this is accomplished, self and cross pollen tubes grow equally fast in the style. In the ovary, however, self tubes grow slowly. Either they fail to reach and enter ovules, or ovules abort in two or more days after fertilization. Simultaneous or sequential

selfing and crossing from mixed pollen or mixed pollinations may lead to interaction of mechanisms and greater set of selfed seed, but the amount of selfed seed still is directly related to the self-fertility of the individual plant. Differential compatibilities among and within selfed, sibbed, and crossed pollinations complicate seed studies, synthesis of new varieties, and genetic studies. Differential bee behavior according to spatial factors, plant genotype, and other conditions add to the complications. The inheritance of self-incompatibility appears to be very complex.

Birdsfoot trefoil commonly produces four to seven florets per flower umbel, with approximately 50 ovules in the ovary of each floret. Under good greenhouse conditions, self pollination of the most self-fertile plants produces about 25 pods and 100 to 125 seeds from each 100 florets pollinated (5,000 ovules). Cross pollinations of 100 florets may give about 90 pods and 1,500 to 1,600 seeds. Thus, 2 percent of the ovules are converted into selfed seed, and 30 percent into crossed seed. In greenhouses with poor light, temperature, and moisture conditions, seed production efficiencies are much lower, and even crossing may become difficult.

Field conditions for seed development vary widely. Theoretically, the crop has the capacity to produce many thousands of pounds of seed per acre in a single crop. Yet we may consider 100 to 200 pounds a big yield, even though it represents perhaps only 1 to 5 percent of the theoretical potential.

Since flower production usually should correlate strongly with seed yield, flower bud abortion is the first and greatest limiting factor following initiation. Other important limiting factors are failure to pollinate and develop into mature seeds, and pod-shatter after maturity. Under reasonably good conditions, the pod set may be 50 to 80 percent, with three or four pods per umbel; the pods will contain an average of 10 or 11 recoverable seeds (after cleaning), over 90 percent of which are hard seeds, weighing 0.8 to 1.2 grams per 1,000 seeds. With such pods, 1 pod per square foot of land equals about 1 pound of seed per acre, a useful generalization for visual estimates of yield.

Individual pods sometimes yield over 30 seeds, and in rare instances over 40 seeds. It is not known what opportunities exist to raise seed yield through more seeds per pod, or whether an increase in seeds would be offset by compensatory losses in other components of seed yield.

Honeybees are the best, leaf–cutter bees the next best, and bumblebees the least effective pollinators of trefoil. Honeybees visit 10 to 12 florets per minute, and a floret may receive 12 to 25 visits if bees are abundant in the four to five days it is open. A population of one bee per square yard (considered adequate) could visit 5,300 florets in one 8-hour day and generate at least 1,400 pods or 155 pounds of seed per acre, even allowing for 50 percent revisitation. Pods are mature about four weeks after pollination and dehisce shortly thereafter if relative humidity is below 40 percent.

Seed production varies greatly from place to place and year to year. Experienced commercial growers normally may expect the Empire types to yield 40 to 125 pounds per acre in northern Missouri; 75 to 150 pounds in southern and central Iowa and in the Northeast; and 100 to 200 pounds in North Dakota. Other areas fall within these ranges. However, yields in any one year may vary from a low of 5 pounds to a high of 500 pounds per acre.

The factors underlying these wide differences in yield are not clear; neither is the way they finally become expressed as components of yield and associated variables. Conditions of light, temperature, rainfall, soil, root and top diseases, harmful insects (chalcid, leafhopper, lygus, plant bugs), bee populations, age, vigor and density of stand, companion grasses, weeds, and defoliation management, all affect seed yield in varying combinations and intensities. Excessively cool, wet weather depresses flowering and interferes with pollination; and hot, dry weather causes pod-shatter. These conditions occur often, and we can relate them to yield components more easily than the other conditions. Often when flowering is severely depressed, pod set and seed set per floret decline also. The ability of trefoil to produce cyclic flushes of bloom from new growth from stem axils or crown buds, depending on the variety, is another complication in assessing seed potentials.

The two basic types of trefoil being used commercially, the semiprostrate Empire type and the more erect European hay type, differ in seed habit. Empire makes seed abundantly on the first spring growth, but sparingly and unreliably on later growths. The hay type tends to make seed sparingly on the first spring growth, but abundantly on the second growth. However, in both types seed yield is negligible in the seedling year, unless plants are put in spaced plantings and established early in the growing season.

Specific genotypes, as clones, differ in seed production. The differences appear to be related mostly to flower production, with other components being involved to a lesser but variable degree. Some of these differences are probably specific interactions of clones with environmental stresses. Others are intrinsic to the clone, for reasons unknown.

There is yet much to be learned about the development of seed potential through successive stages of buds, flowers, ovules, pods, and seeds; about the associations of stages among themselves, with other plant traits, and with environmental pressures and conditions; and about the variation of these relationships among genotypes. Information is likewise lacking on compensatory relationships among components of seed yield.

MATERIALS AND METHODS

Thirty clones were selected from the breeding programs of the Agricultural Experiment Stations at Illinois (8 clones), Iowa (6 clones), Minnesota (7 clones), and Missouri (9 clones). Each clone was vegetatively propagated to establish five replications of two-plant plots at Urbana, Illinois; Ames, Iowa; Rosemount, Minnesota; Columbia, Missouri; Fargo, North Dakota; and Corvallis, Oregon. Most vegetative increases were made at the station of origin and rooted cuttings were distributed to the stations where the plants were grown.

The rooted cuttings were always started in soil in peat pots before being transplanted in the field nursery. The spacing between plants varied among stations, but were never less than 36 inches or more than 48 inches in each direction.

Growing conditions appeared to be near normal at each location. Soil types and precipitation and temperature data for 1969 and 1970 are given in Table 1.

The following independent variables were measured or visually estimated at one or more of the six test locations in 1969 and 1970:

1. Plant vigor: recorded as visual estimate, 1 = most vigorous, 5 = least vigorous.
2. Erectness of growth: recorded as visual estimate, 1 = most erect, 5 = most prostrate.
3. Plant height: measured in inches.
4. Stem length: average of 10 stems measured from crown to tip (cm).
5. Number of stems per plant: counted number.
6. Umbels per plant: average number of umbels on 10 stems multiplied by total number of stems.
7. Number of flowers per umbel: average number of flowers per umbel on 10 stems.
8. Number of pods per umbel: average number of pods per umbel on 10 stems.
9. Seeds per umbel: average number of seeds in 10 representative umbels.
10. Weight per 100 seeds (mg).
11. Total seed yield per plant (gm).
12. Visual estimate of seed yield: 1 = best, 5 = poorest yield.
13. Barren flowers: estimated percent of flowers which did not produce pods.
14. Dry weight per plant: weight of total dried plant before threshing (gm).
15. Maturity: date of harvest.
16. Honeybees per plant: number of honeybees observed in a two-plant plot during a given moment.
17. Plant width: crown diameter (cm).

Not all propagules survived. Therefore, plant measurements were averaged within plots prior to analyses of variance. Statistical significance of differences among clonal means was tested by using the least significant difference (LSD) at a probability level of $\alpha = .05$. All correlation and regression analyses were computed using entry means.

Table 1. — Environmental Data for Birdsfoot Trefoil Clonal Seed Study: April Through September, 1969 and 1970

	Illinois, Drummer silty clay loam		Iowa, Webster silty clay loam		Minnesota, Port Byron silt loam		Missouri, Putnam silt loam		North Dakota, Fargo clay		Oregon, Woodburn silt loam	
	1969	1970	1969	1970	1969	1970	1969	1970	1969	1970	1969	1970
Precipitation, in.												
April	6.00	7.71	4.11	1.67	1.75	3.39	5.99	6.58	1.55	2.30	1.94	2.66
May	1.71	1.72	3.21	7.48	2.26	6.24	3.95	8.96	2.36	2.83	1.64	1.12
June	1.82	3.26	5.96	3.15	3.41	2.57	10.14	4.48	2.03	2.63	2.46	.53
July	2.98	4.58	4.90	3.79	2.83	5.16	5.32	1.54	5.92	.43	.05	.12
August	3.30	3.12	2.02	5.76	.97	1.63	1.55	8.40	.38	1.24	trace	trace
September	5.74	6.99	4.48	5.32	.58	4.96	7.56	9.27	1.55	3.61	3.62	1.06
Average maximum daily air temperature, °F.												
April	64.0	63.8	62.4	64.4	59.7	56.1	68.0	66.0	55.2	47.6	58.7	55.9
May	74.8	77.2	73.4	77.0	72.9	70.7	74.5	77.0	68.0	62.1	70.0	66.6
June	80.5	81.2	76.8	81.8	72.1	82.7	79.8	80.2	68.2	79.3	74.5	77.4
July	87.1	85.1	83.6	86.1	84.0	85.7	90.4	89.0	79.5	85.0	78.9	82.4
August	85.2	82.9	83.9	82.5	85.9	83.5	87.2	84.5	86.0	83.5	79.0	81.9
September	77.0	80.0	75.3	75.0	75.6	71.3	79.1	79.4	70.8	71.5	74.8	71.9
Average minimum daily air temperature, °F.												
April	42.7	44.0	39.0	38.2	39.4	33.1	46.9	45.4	35.6	30.5	37.6	36.9
May	52.4	54.8	49.9	51.7	47.5	47.8	54.8	56.7	41.6	41.3	45.8	42.0
June	58.6	60.8	54.0	59.3	55.5	58.2	60.8	62.1	46.4	56.4	53.6	50.2
July	67.6	64.2	64.5	61.7	58.5	59.0	70.6	64.6	57.2	58.5	49.7	50.2
August	63.3	63.6	61.3	61.2	56.5	56.7	66.3	66.4	58.7	55.9	47.9	48.9
September	56.1	57.9	52.4	52.9	47.0	48.2	58.8	60.4	47.1	47.8	48.9	45.4

RESULTS AND DISCUSSION

Morphological Characteristics

Between the first and second year of growth, the various clones displayed very little difference in vigor, erectness, height, maturity, flowers per umbel, pods per umbel, and seed weight per 100 seeds (Table 2). As one would expect, number of stems per plant, umbels per plant, dry weight, seeds per umbel, and total seed yield increased during the second year of growth. These increases were primarily due to the increased growth and size of the crown. Probably because of a greater number of flowers and more highly developed root systems in the second year, both pod length and the number of barren flowers decreased. Some propagules were so weak the first year that significant data could not be collected, and since other propagules died during the second year, clonal means for them are absent. For most morphological characteristics, differences did oc-

Table 2. — Clonal Means in the North Central States and Oregon in 1969 and 1970

Clone number	Vigor[a]		Erectness[b]		Height, cm.		Stems per plant		Umbels per plant	
	1969(5)[c]	1970(5)	1969(4)	1970(5)	1969(3)	1970(4)	1969(3)	1970(5)	1969(5)	1970(5)
1 MO 9	3.6	3.0	3.0	2.8	28	34	12	71	182	1465
2 MO 17	3.9	2.4	3.2	2.8	30	34	16	103	149	1323
3 MO 20	3.0	1.7	3.2	3.4	35	39	15	119	215	2077
4 MO 25	4.0	2.3	3.8	3.6	32	34	10	74	139	1730
5 MO 41	4.1	3.5	4.8	3.6	33	27	10	60	92	845
6 MO 73	3.2	2.3	3.3	3.4	35	36	13	120	151	1548
7 MO 143	3.5	2.5	4.1	3.0	30	34	14	96	115	1175
8 MO 173	2.6	...	2.8	...	28	32	24	...	183	...
9 MO 180	3.5	2.6	4.4	2.9	31	34	12	83	106	1067
10 ILL 9	2.0	2.5	3.4	3.6	38	31	27	91	391	2378
11 ILL 13	...	...	...	...	38	34	...	...	...	...
12 ILL 38	2.5	2.1	4.3	3.7	37	34	26	110	323	1684
13 ILL 41	2.4	1.8	4.2	3.6	38	36	21	136	271	2218
14 ILL 42	3.3	2.0	3.8	3.9	32	36	16	104	221	1246
15 MT 23	2.9	...	4.1	...	32	...	24	...	249	...
16 MT 26	2.9	3.3	4.7	3.9	37	27	12	101	178	1555
17 MT 31	2.7	2.2	4.6	3.8	32	34	21	123	188	2313
18 ILL 44	3.1	2.0	3.6	3.5	34	34	21	90	266	1474
19 MT 59	2.6	2.5	3.0	2.8	36	39	17	78	273	1524
20 MT 142[d]	...	...	...	...	...	...	...	...	...	...
21 MT 201	2.7	2.3	4.4	3.9	32	35	21	90	229	2054
22 MT 202	2.8	2.9	1.4	1.6	32	37	14	105	174	1023
23 ILL 10	...	...	...	...	34	37	...	...	...	...
24 ILL 28	2.4	...	3.5	...	38	...	24	...	254	...
25 IA E 12-1	3.3	2.4	3.4	3.2	35	33	11	63	126	1587
26 IA E 15-15	...	3.1	4.7	4.5	37	27	12	55	150	1142
27 IA E 20-15	3.4	...	2.8	...	31	28	15	...	...	...
28 R 9-5	...	2.7	3.2	2.8	39	35	15	65	...	1226
29 R 14-7	...	1.9	3.2	3.1	38	38	15	90	...	1589
30 R 22-3	...	3.0	4.2	3.9	40	29	18	68	...	1206
Average	3.1	2.5	3.7	3.4	34	33	17	91	201	1541
LSD .05	.7	.9	.7	.7	6	7	9.6	33.3	151.4	ns

[a] 1 = most vigorous; 5 = weakest.

[b] 1 = erect; 5 = prostrate.

[c] Figures in parentheses indicate the number of tests in which the trait was measured.

[d] Clone died before data could be collected.

(Table 2 continued on p. 6.)

cur among clones as indicated by the LSD's as shown in Table 2.

Clonal means for three components of seed yield in Oregon, North Dakota, and Minnesota are presented for the first year of growth in Table 3, and for the second year in Table 4. Since Oregon has long been a good seed-producing state, it was used as the standard of comparison for North Dakota and Minnesota. Albrechtsen *et al.* (*1*) studied various components of seed yield. Based on their findings, we chose umbels per plant, flowers per umbel, and pods per umbel as the major potential components contributing to phenotypic variation in seed yield. Significant differences among the clones in this study were found for all three traits in each year at each location (Tables 3 and 4).

In the first year, 1969, the most umbels per plant were produced in North Dakota, but during the second year of growth, umbels per plant in Minnesota increased almost 25 times (Tables 3 and 4). The coefficients of variations were rather high for this characteristic at all three locations. Considerable human error involved in the actual counting may have contributed to this variability.

Very little difference occurred between years or locations for flowers per umbel and pods per umbel (Tables 3 and 4). As indicated by the coefficients of variation, differences among clones could be determined more precisely for these two components of seed yield than for the number of umbels per plant.

One can examine the summary of coefficients of vari-

Table 2. — Continued

Clone number	Pod length, mm.		Barren flowers		Dry wt. per plant, gm.		Maturity[e]		Flowers per umbel	
	1969(4)	1970(5)	1969(2)	1970(3)	1969(3)	1970(3)	1969(3)	1970(4)	1969(5)	1970(5)
1 MO 9	21.3	19.3	22	16	36	313	184	183	4.7	4.8
2 MO 17	19.8	16.8	16	22	24	294	182	181	5.1	5.5
3 MO 20	21.0	19.6	17	21	48	447	188	185	5.2	5.0
4 MO 25	20.6	17.6	20	16	21	310	180	179	5.1	5.5
5 MO 41	21.0	18.4	21	13	26	182	190	188	4.2	4.9
6 MO 73	21.4	17.6	21	17	50	437	185	186	4.5	4.9
7 MO 143	16.8	12.3	20	25	43	346	191	150	5.2	...
8 MO 173	16.8	...	24	10	74	...	192	...	4.0	...
9 MO 180	17.0	15.7	16	18	39	337	189	188	4.9	5.0
10 ILL 9	20.1	16.1	24	23	117	472	192	193	5.1	5.0
11 ILL 13	...	...	22	24	...	...	189	...	...	...
12 ILL 38	20.7	18.1	19	11	88	486	186	185	4.7	4.8
13 ILL 41	11.1	12.2	50	26	80	440	196	196	4.9	4.9
14 ILL 42	19.6	17.7	19	38	50	422	187	187	4.8	4.8
15 MT 23	19.7	...	21	...	51	...	191	...	4.5	...
16 MT 26	18.5	16.1	22	12	58	289	192	195	5.2	5.2
17 MT 31	17.2	17.6	30	24	75	555	195	192	5.2	5.1
18 ILL 44	21.5	20.7	17	12	65	322	182	180	4.9	5.0
19 MT 59	19.7	17.0	24	19	65	299	182	182	4.4	4.6
20 MT 142[d]	...	...	...	...	...	...	...	...	...	...
21 MT 201	18.0	17.0	23	20	76	476	188	186	5.3	5.6
22 MT 202	21.1	18.1	24	9	48	228	182	180	3.7	4.0
23 ILL 10	...	...	25	18	...	...	190	...	...	...
24 ILL 28	14.3	...	28	...	99	427	196	...	4.1	...
25 IA E 12-1 ...	19.9	19.5	19	19	46	410	193	187	5.0	6.0
26 IA E 15-15 ..	19.9	17.0	...	16	48	226	...	191		5.4
27 IA E 20-15 ..	21.5	...	20	13	49	...	187	...	4.1	...
28 R 9-5	22.0	19.5	...	13	73	496	...	179	...	4.9
29 R 14-7 ...	22.1	19.4	...	16	59	626	...	186	...	4.6
30 R 22-3 ...	20.7	14.3	...	16	64	194	...	144	...	...
Average	19.4	17.3	23	18	58	376	188	183	4.7	5.0
LSD .05	1.5	3.7	ns	21	35	188	ns	ns	.4	.5

[e]Number of days beyond January 1 to first blooms.

(Table 2 concluded on p. 7.)

ation in Table 5 and compare the two years' data. Some characters were precisely measured at each location and year, such as flowers per umbel and pods per umbel. However, several characters, such as umbels per plant and total seed yield in Oregon and Minnesota, were unreliably measured.

Simple Correlations

The degree of association between independent variables and seed yields in Oregon, North Dakota, and Minnesota was measured by computing simple correlation coefficients (r) for each location involved in this study (Tables 6 through 11). Not all traits were measured in all states each year.

Approximately one-fourth of the values were statistically significant, although some of the correlations were too low to be of any practical benefit in a breeding program. The coefficients of determination, r^2, reported in Tables 6 through 11, express that proportion of observed variation in a dependent trait due to variation in the independent trait.

It is obvious that no single independent variable accounts for the variation in seed yields among clones grown in different locations. For all states except Missouri, pods per umbel were fairly consistently correlated with seed yields in Oregon, North Dakota, and Minnesota (Tables 6 through 11). Correlations were more uniform from year to year in Minnesota than in other states. In addition to pods per umbel, seeds per umbel accounted significantly for the variation in seed yields measured in Oregon, North Dakota, and Minnesota, especially during the second year of seed production (Tables 6 through 8).

Table 2. — Concluded

Clone number	Pods per umbel		Seeds per umbel		Seed wt. per 100 seeds, mg.		Total seed yield, gm.		Plant width, cm.	Visual seed yield[f]
	1969(5)	1970(5)	1969(3)	1970(3)	1969(4)	1970(4)	1969(3)	1970(5)	1970(4)	1970(4)
1 MO 9	3.0	3.1	16.2	34.7	103	122	2	23	59.3	2.4
2 MO 17	3.4	3.0	12.7	28.2	121	118	2	11	67.2	2.5
3 MO 20	3.5	3.3	17.8	42.8	87	88	3	31	79.0	2.7
4 MO 25	3.4	3.7	11.9	31.9	123	132	2	25	73.2	2.3
5 MO 41	2.7	3.0	12.0	27.4	103	116	2	11	53.4	2.7
6 MO 73	2.8	2.9	12.8	31.8	117	121	2	19	71.0	2.8
7 MO 143	2.7	...	7.8	32.6	115	...	1	...	58.8	4.0
8 MO 173	3.2	...	9.6	...	94	104	3	...	...	3.8
9 MO 180	2.7	2.5	7.7	17.4	119	122	1	5	61.7	3.8
10 ILL 9	3.1	3.1	10.3	23.8	137	119	4	16	59.6	3.2
11 ILL 13	...	...	...	...	...	122	...	...	...	3.2
12 ILL 38	3.9	3.7	13.0	36.4	140	139	7	35	77.0	2.5
13 ILL 41	1.6	1.8	2.9	9.1	134	130	1	4	81.3	3.5
14 ILL 42	3.3	3.2	12.5	33.8	132	117	4	24	73.7	2.6
15 MT 23	3.7	...	9.9	...	138	...	4	...	...	...
16 MT 26	3.8	3.4	11.3	27.8	123	125	5	21	58.5	3.4
17 MT 31	3.5	3.1	8.1	23.0	119	118	7	18	74.6	3.3
18 ILL 44	3.9	3.8	14.2	43.5	122	122	6	34	68.2	1.6
19 MT 59	3.3	3.2	10.0	26.2	133	141	2	12	69.8	2.5
20 MT 142[d]	...	...	...	...	...	...	...	...	...	...
21 MT 201	3.7	3.4	9.5	29.4	151	143	4	24	66.7	2.8
22 MT 202	2.8	3.0	14.6	28.9	121	114	4	15	51.4	2.5
23 ILL 10	...	...	...	...	...	128	...	...	...	3.1
24 ILL 28	2.3	...	6.0	...	129	...	1	...	...	...
25 IA E 12-1	3.5	3.3	12.1	32.6	145	143	4	27	67.9	2.4
26 IA E 15-15	...	2.8	...	20.6	...	137	...	11	54.7	3.6
27 IA E 20-15	2.9	...	7.7	...	163	177	2	...	...	3.3
28 R 9-5	...	2.6	...	23.0	...	110	...	12	61.4	3.5
29 R 14-7	...	2.7	...	26.8	...	134	...	20	76.8	2.9
30 R 22-3	...	...	...	29.0	...	...	...	...	56.7	3.8
Average	3.2	3.1	10.9	28.7	125	126	3	19	66.2	3.0
LSD .05	.7	.5	2.8	10.9	17	15	3	13	17.2	.9

[f] 1 = greatest seed producer; 5 = least seed producer.

Stepwise Regression

Stepwise regression analyses were performed to predict seed yields in various states from different independent variables in both 1969 and 1970. Terminal equations were established with the multiple correlation R approximating .90 (Tables 12 to 19). This end point of R = .90 was arbitrary and reflects the authors' opinion that such a value would be high enough to give a reasonably accurate prediction in a breeding program. The complete equations generated for the data in this study are available from the senior author.

As noted earlier, Oregon, North Dakota, and Minnesota were thought to be important potential producers of birdsfoot trefoil seed. Table 12 identifies which independent variables from which states are the most important in predicting first-year seed yields. Pods per umbel measured in Oregon accounted for the largest amount of variability when predicting seed yield in Oregon. Inclusion of stems per plant measured in North Dakota, Illinois, and Iowa, plus dry weight in Iowa, results in a terminal multiple correlation of R = .9039. For seed yield in North Dakota, three variables, North Dakota dry weight and pod length plus number of pods per umbel measured in Illinois, gave an R of .9030. For Minnesota seed yield, six variables were needed to attain R = .9152. One can easily see that the number of pods per umbel is very important in predicting seed yields. It is interesting to note that various Minnesota variables are more important than variables from other

Table 3. — Clonal Means of Characters Measured in the First Year of Growth (1969) in Oregon, North Dakota, and Minnesota

Clone number	Umbels per plant			Flowers per umbel			Pods per umbel		
	Oreg.	N.Dak.	Minn.	Oreg.	N.Dak.	Minn.	Oreg.	N.Dak.	Minn.
1 MO 9	118	132	136	4.8	4.4	5.3	2.8	2.7	3.8
2 MO 17	98	194	124	5.2	5.0	5.8	3.5	3.2	3.7
3 MO 20	120	220	186	5.0	5.3	6.4	3.6	3.2	3.9
4 MO 25	150	91	109	5.1	5.0	5.9	3.7	3.4	3.1
5 MO 41	62	110	95	4.2	4.4	4.7	2.1	3.1	3.4
6 MO 73	118	117	195	4.2	4.4	5.7	2.7	3.0	2.9
7 MO 143	85	216	103	5.1	5.4	6.0	1.0	2.9	4.0
8 MO 173	182	293	204	4.6	4.8	5.2	3.2	3.8	4.3
9 MO 180	72	159	96	5.0	5.1	5.3	1.6	2.7	3.3
10 ILL 9	109	334	198	4.7	5.2	6.1	3.6	3.0	3.7
11 ILL 13	104	...	240	4.6	...	5.7	3.5	...	3.7
12 ILL 38	160	300	189	4.6	4.4	5.4	3.7	3.5	4.1
13 ILL 41	145	277	210	4.7	4.9	5.5	0.8	1.8	2.0
14 ILL 42	172	186	175	5.1	4.6	5.3	3.4	3.3	3.9
15 MT 23	152	244	162	4.7	4.3	5.2	3.8	3.5	4.3
16 MT 26	139	137	140	5.0	5.2	6.0	3.9	3.2	5.0
17 MT 31	174	231	147	5.6	4.8	5.7	4.0	3.2	4.6
18 ILL 44	170	247	128	4.8	5.2	5.2	4.2	4.0	3.5
19 MT 59	147	147	141	4.8	4.7	5.1	4.0	2.6	4.0
20 MT 142	182	...	276	5.5	...	6.0	4.0	...	4.3
21 MT 201	169	253	132	5.4	5.4	6.0	4.1	3.2	4.4
22 MT 202	165	235	144	3.7	3.8	4.8	2.9	2.6	3.6
23 ILL 10	186	...	94	5.1	...	5.2	3.1	...	3.8
24 ILL 28	150	190	73	4.4	4.6	3.5	0.7	2.8	3.2
25 IA E 12-1	113	118	92	5.5	5.2	5.2	4.1	3.5	3.4
26 IA E 15-15	...	126	121	..	5.1	5.5	...	3.0	4.3
27 IA E 20-15	123	188	157	4.4	4.1	5.0	2.4	3.4	3.8
28 R 9-5	...	196	205	...	5.0	6.0	...	2.6	3.7
29 R 14-7	...	164	157	...	5.1	5.9	...	2.8	4.1
30 R 22-3	...	215	146	...	5.2	5.3	...	2.8	3.7
Average	137	197	152	4.8	4.8	5.5	3.1	3.1	3.8
LSD .05	36	111	68	0.5	0.7	0.9	0.8	0.5	1.0
C.V. (percent)	18	39	35	7	10	11	16	11	22

states for predicting Minnesota seed yields. On the other hand, when one predicts seed yields in Oregon, only one variable from Oregon, number of pods per umbel, is important; the four other variables are from three other states.

Table 13 shows the independent variables at each of four midwestern locations that were most useful for predicting Oregon seed yields. Similiar information is given for North Dakota and Minnesota in Tables 14 and 15. Again the number of pods per umbel was the most important variable. No other variable appeared as consistently in the predicting equations.

Table 16 presents equations for predicting second-year seed yields in Oregon, North Dakota, and Minnesota, using independent variables from all states. The most important variables in these equations are quite different from those in the first-year predictive equations (compare Table 12 with Table 16). During the second year, North Dakota and Minnesota seed yields were best predicted from using their own variables rather than those from other states. Measuring seed yield in Minnesota was a good method for predicting seed yield in Oregon.

Equations for predicting second-year Oregon yields from various independent variables in four North Central states are given in Table 17. Total seed yields measured in Minnesota, North Dakota, and Missouri were quite important. Erectness measured in Minnesota, Illinois, and Missouri was also valuable.

Total seed yield plus stems per plant, measured in North Dakota, were valuable for predicting both first-year and second-year seed yields in Oregon (Tables 13

Table 4. — Clonal Means of Characters Measured in the Second Year of Growth (1970) in Oregon, North Dakota, and Minnesota

Clone number	Umbels per plant			Flowers per umbel			Pods per umbel		
	Oreg.	N.Dak.	Minn.	Oreg.	N.Dak.	Minn.	Oreg.	N.Dak.	Minn.
1 MO 9	276	1536	2794	5.6	5.2	5.2	2.6	3.2	3.5
2 MO 17	284	1711	2720	6.4	6.2	5.9	2.3	3.8	3.2
3 MO 20	342	2992	6373	5.6	5.5	4.9	3.0	4.5	3.8
4 MO 25	288	2016	4720	6.9	6.2	5.0	3.4	4.5	3.9
5 MO 41	232	1404	1804	5.8	5.0	5.3	2.6	3.5	3.1
6 MO 73	328	2184	3220	5.3	5.0	4.8	2.8	4.0	3.0
7 MO 143	153	1736	4343	4.5	6.0	6.2	1.4	3.0	3.2
8 MO 173	170	...	5023	4.8	...	4.7	3.6	...	4.3
9 MO 180	184	1980	3718	5.8	6.0	6.0	2.0	3.0	3.2
10 ILL 9	212	2847	5249	5.6	5.5	6.0	3.2	2.8	4.1
11 ILL 13	266	...	5640	5.6	...	6.0	3.0	...	3.9
12 ILL 38	327	2538	4378	5.6	5.2	5.1	3.6	4.0	4.5
13 ILL 41	434	4092	5970	5.4	5.5	5.3	0.3	1.2	2.3
14 ILL 42	249	2697	3388	5.4	5.8	5.3	3.3	3.5	3.8
15 MT 23	...	630	637	...	4.0	1.0	...	0.8	0.6
16 MT 26	226	1566	5105	6.0	6.0	5.8	2.9	4.0	4.5
17 MT 31	280	3706	4300	5.6	5.8	5.5	2.9	3.2	4.1
18 ILL 44	258	2300	2677	5.6	5.8	5.4	3.4	4.5	4.8
19 MT 59	298	1386	3252	5.0	5.0	4.8	2.6	3.5	3.6
20 MT 142	...	...	2969	...	...	6.7	...	...	4.0
21 MT 201	172	3060	6099	5.8	6.5	6.0	3.1	3.8	4.4
22 MT 202	203	1127	2244	4.5	3.8	4.2	2.8	2.8	3.7
23 ILL 10	330	...	4248	6.1	...	4.7	2.8	...	3.9
24 ILL 28	...	2040	2931	...	5.0	5.2	...	2.8	3.3
25 IA E 12-1	149	3111	2924	6.6	6.2	6.8	3.0	3.8	4.4
26 IA E 15-15	130	3520	2758	6.1	6.5	5.7	2.9	3.0	3.3
27 IA E 20-15	190	...	1878	5.1	...	4.8	1.8	...	3.6
28 R 9-5	96	1628	3049	5.5	5.8	5.2	1.9	3.2	3.2
29 R 14-7	233	4662	4116	5.5	5.5	5.3	2.4	2.5	3.5
30 R 22-3	131	2964	4043	6.3	6.5	6.2	2.2	2.5	4.0
Average	237	2368	3752	5.6	5.6	5.3	2.7	3.2	3.6
LSD .05	147	140	2364	1.0	1.2	0.9	0.8	1.0	0.7
C.V. (percent)	30	30	44	12	15	12	20	20	14

and 17). However, 11 North Dakota variables were needed to attain a multiple correlation of about .90 for second-year Oregon seed yields. It is impractical in plant breeding to measure more than five or six characters to predict seed yields at another location.

Seed yields in North Dakota required only two characters measured in that state, pod length and vigor, to give a multiple correlation of .92 (Table 18). Total seed yields in Minnesota, Illinois, and Missouri accounted for a great deal of the variation when predicting seed

Table 5. — Summary of Coefficients of Variation (Percent) of Traits Measured in the 6 States, 1969 and 1970

Character measured	Oregon		N. Dakota		Minnesota		Illinois		Iowa	Missouri
	1969	1970	1969	1970	1969	1970	1969	1970	1969	1970
Plant vigor	17	20	25	38	22	25	21	40	29	14
Erectness	...	12	18	29	17	13	16	19	17	9
Height	...	16	...	...	15	12	11	19	9	13
Stems/plant	...	18	33	31	...	28	26	40	49	22
Umbels/plant	18	30	39	30	35	44	39	36	59	38
Pod length	...	10	6	21	16	15	9	8	6	6
Barren flowers	31	19	...	...	...	...	...	114	35	25
Dry wt./plant	...	...	26	23	...	...	43	41	35	33
Maturity	1	...	...	10	3	...	3	11	...	8
Flowers/umbel	7	12	10	15	11	12	15	18	11	11
Pods/umbel	16	20	11	20	22	14	26	20	2	25
Seeds/umbel	21	...	16	22	...	30	...	46	19	...
Total seed yield	51	47	46	33	61	32	...	55	...	66
Seed wt./100 seeds	8	19	6	...	...	15	14	19	6	4
Plant width	...	14	16	16	...	...	...	21	...	10
Seeds/10 umbels	...	36	...	...	32	...	...	...	...	...
Visual seed yield	...	21	...	...	24	31	...	29	...	8
Honeybees/plot	...	...	...	...	88	41	...	...	...	...

Table 6. — Simple Correlation Coefficients for Characters Measured in Oregon in 1969 and 1970, and Seed Yields in Oregon, North Dakota, and Minnesota During the Same Years

Character measured in Oregon	Oregon		North Dakota		Minnesota	
	1969	1970	1969	1970	1969	1970
Plant vigor	-.46*	-.09	-.24	-.13	-.01	-.37
Erectness	...	.21	.09	.19	.21	.47*
Height	...	-.11	...	...	.21	.36
Stems/plant	...	-.20	-.47*	.32	...	.21
Umbels/plant	.59**	.26	.32	-.23	.14	.16
Flowers/umbel	.31	-.04	-.02	-.03	.12	-.18
Pods/umbel	.70**	.70**	.58**	.58**	.47*	.65**
Seeds/umbel	.49*	...	.19	.53	...	.72**
Seed wt./100 seeds	.16	-.10	.17	...	...	.04
Total seed yield	...	...	.56**	.64**	.41	.77**
Pod length	...	.45*	.34	.54	.36	.29
Barren flowers	-.13	-.66*	...	...	...	...
Maturity	-.49*	.06	...	-.18	.16	...
Visual seed yield	...	-.64**	...	...	-.16	-.28
Seeds/10 umbels	...	.84**	...	...	.38	...
Plant width	...	.19	.06	.15	...	...

* P <.05. ** P <.01.

yields in North Dakota. Only five Illinois characters were needed to predict North Dakota seed yields, while eight and fourteen characters were required in Minnesota and Missouri, respectively (Table 18).

Minnesota data were best for predicting second-year seed yields in Minnesota (Table 19). Total seed-yield measurements in North Dakota and Missouri best predicted second-year seed yields in Minnesota from data of those states, while seeds per umbel measured in Illinois was the best single character for that state. Again, too many characters were needed from Missouri to accurately predict second-year seed yields in Minnesota (Table 19).

It appears that number of pods per umbel is the most important character for measuring first-year seed production (Tables 12 to 15). Predicting second-year seed yields is more difficult and variable. Total seed-yield measurements in other states were the best predictors, but erectness ratings and umbels per plant were also important (Tables 16 to 19).

Table 7. — Simple Correlation Coefficients for Characters Measured in North Dakota in 1969 and 1970, and Seed Yields in Oregon, North Dakota, and Minnesota During the Same Years

Character measured in North Dakota	Oregon		North Dakota		Minnesota	
	1969	1970	1969	1970	1969	1970
Plant vigor	-.24	-.13	-.29	-.17	-.43*	-.22
Erectness	.09	.19	.05	.15	.03	.16
Stems/plant	.47*	.32	.38	.12	.35	.16
Umbels/plant	.32	-.23	.42*	-.17	.26	.07
Flowers/umbel	-.02	-.03	-.02	-.02	.12	.10
Pods/umbel	.58**	.58**	.50*	.63**	.19	.61**
Seeds/umbel	.19	.53	.32	.82**	.22	.59**
Seed wt./100 seeds	.17	...	.08	...	-.23	...
Total seed yield	.56**	.64**	...	...	.41*	.75**
Pod length	.34	.54	.48*	.82**	.09	.58**
Dry wt./plant	.27	.02	.60**	-.01	.27	.17
Maturity	...	-.18	...	-.52*	...	-.22
Plant width	.06	.15	.38	.17	.03	.22

* P <.05. ** P <.01.

Table 8. — Simple Correlation Coefficients for Characters Measured in Minnesota in 1969 and 1970, and Seed Yields in Oregon, North Dakota, and Minnesota During the Same Years

Character measured in Minnesota	Oregon		North Dakota		Minnesota	
	1969	1970	1969	1970	1969	1970
Plant vigor	-.01	-.37	-.35	-.22	-.36	-.47*
Erectness	.21	.47*	-.17	.16	.11	.24
Height	.21	.36	.34	...	.43*	.42
Stems/plant	...	.21	...	.16	...	.01
Umbels/plant	.14	.16	.34	.07	.44*	.17
Flowers/umbel	.12	-.18	.04	.10	.45*	.13
Pods/umbel	.47*	.65**	.44*	.61**	.62**	.81**
Seeds/umbel	.38	.72**	.20	.59**	.66**	.82**
Total seed yield	.41	.77**	.41**	.75**	...	...
Pod length	.36	.29	.35	.58**	.23	.43
Maturity	.16	...	-.01	-.22	.09	...
Visual seed yield	-.16	-.28	-.40	...	-.43*	-.58

* P <.05. ** P <.01.

Table 9. — Simple Correlation Coefficients for Characters Measured in Illinois in 1969 and 1970, and Seed Yields in Oregon, North Dakota, and Minnesota During the Same Years

Character measured in Illinois	Oregon		North Dakota		Minnesota	
	1969	1970	1969	1970	1969	1970
Plant vigor	.25	-.14	-.15	-.06	-.05	-.03
Erectness	.11	.19	-.12	-.14	.25	.04
Height	-.21	.06	.09	.01	.01	-.16
Stems/plant	-.19	.06	.15	-.14	-.06	-.10
Umbels/plant	.13	-.03	.42*	.21	.35	.17
Flowers/umbel	.32	.30	.07	.45	.18	.60**
Pods/umbel	.58**	.67**	.47*	.54	.38	.63**
Seeds/umbel	...	.72**	...	.73**	...	.70**
Seed wt./100 seeds	.21	-.12	.44*	-.10	.14	-.02
Total seed yield	...	.64**	...	.67**	...	.59**
Pod length	.27	.29	.34	.70**	.14	.59**
Dry wt./plant	-.37	.08	-.18	-.01	.02	.07
Barren flowers	...	.06	...	.03	...	-.17
Maturity	-.11	-.12	-.19	-.46*	.23	-.17
Visual seed yield	...	-.22	...	-.41	...	-.30
Plant width	...	.09	...	-.07	...	-.18

* P <.05. ** P <.01.

Table 10. — Simple Correlation Coefficients for Characters Measured in Iowa in 1969, and Seed Yields in Oregon, North Dakota, and Minnesota During the Same Year

Character measured in Iowa	Oreg. 1969	N.Dak. 1969	Minn. 1969
Plant vigor	-.29	-.49*	-.34
Erectness	.16	-.13	.37
Height	.01	.26	.19
Stems/plant	.26	.26	.09
Umbels/plant	.27	.38	.19
Flowers/umbel	.15	-.16	.30
Pods/umbel	.66**	.46*	.23
Seeds/umbel	.12	.26	.18
Seed wt./100 seeds	.05	.14	-.10
Pod length	.22	.38	.13

* P <.05. ** P <.01.

Table 11. — Simple Correlation Coefficients for Characters Measured in Missouri in 1970, and Seed Yields in Oregon, North Dakota, and Minnesota During the Same Year

Character measured in Missouri	Oreg. 1970	N. Dak. 1970	Minn. 1970
Plant vigor	-.37	-.44*	-.41
Erectness	.23	.05	.29
Height	.02	.29	.12
Stems/plant	.44*	.27	.26
Umbels/plant	.21	-.13	.18
Flowers/umbel	-.06	-.20	-.03
Pods/umbel	.14	.20	.14
Seed wt./100 seeds	-.10	-.09	.04
Total seed yield	.47*	.46*	.49*
Pod length	.19	.17	.27
Dry wt./plant	.54*	.32	.47*
Barren flowers	.03	-.32	.01
Maturity	-.12	-.34	-.09
Visual seed yield	-.15	-.18	-.10
Plant width	.52*	.40	.56**

* P <.05. ** P <.01.

Table 12. — Summary of Stepwise Regression for Predicting 1969 Oregon, North Dakota, and Minnesota Seed Yields From Various Independent Variables in 1969 (Terminal Equations Are Those With Multiple Correlation, R, Approximating .90)

Step No.	Variable entered	Oreg. R	Variable entered	N.Dak. R	Variable entered	Minn. R
1	Oreg. pods/umbel	.7045	N.Dak. dry wt.	.5973	Minn. pods/umbel	.6227
2	N.Dak. stems/plant	.7817	N.Dak. pod length	.8442	Minn. height	.7821
3	Ill. stems/plant	.8588	Ill. pods/umbel	.9030	Oreg. vigor	.8253
4	Iowa stems/plant	.8830			N.Dak. seed wt./100 seeds	.8600
5	Iowa dry wt.	.9039			Minn. maturity	.8880
6					Minn. visual seeds	.9152

Table 13. — Summary of Stepwise Regression for Predicting 1969 Oregon Seed Yield From Different North Central States With Various Independent Variables in 1969 (Terminal Equations Are Those With Multiple Correlation, R, Approximating .90)

Step No.	Iowa	R	North Dakota	R	Minnesota	R	Illinois	R
1	Pods/umbel	.8302	Total seed yield	.8586	Pods/umbel	.8171	Pods/umbel	.8519
2	Vigor	.8713	Stems/plant	.8700	Visual seed	.8405	Height	.8641
3	Height	.9074	Umbels/plant	.8948	Erectness	.8543	Pod length	.8657
4			Dry wt.	.9073	Flowers/umbel	.8704	Vigor	.8682
5					Pod length	.8822	Umbels/plant	.8731
6					Umbels/plant	.8867	Erectness	.8812
7					Maturity	.8881	Stems/plant	.8841
8					Height	.8897		

Table 14. — Summary of Stepwise Regression for Predicting 1969 North Dakota Seed Yield From Different North Central States With Various Independent Variables in 1969 (Terminal Equations Are Those With Multiple Correlation, R, Approximating .90)

Step No.	Iowa	R	North Dakota	R	Minnesota	R	Illinois	R
1	Pods/umbel	.9189	Dry wt.	.9322	Pods/umbel	.9186	Pods/umbel	.9224
2	Vigor	.9439	Seeds/umbel	.9542	Vigor	.9363	Umbels/plant	.9341

Table 15. — Summary of Stepwise Regression for Predicting 1969 Minnesota Seed Yield From Different North Central States With Various Independent Variables in 1969 (Terminal Equations Are Those With Multiple Correlation, R, Approximating .90)

Step No.	Iowa	R	North Dakota	R	Minnesota	R	Illinois	R
1	Erectness	.8852	Stems/plant	.8753	Pods/umbel	.9021	Pods/umbel	.8872
2	Seeds/umbel	.8991	Seeds/pod	.8993	Vigor	.9499	Umbels/plant	.8987
3							Dry wt.	.9035

Table 16. — Summary of Stepwise Regression for Predicting 1970 Oregon, North Dakota, and Minnesota Second-Year Seed Yields From Various Independent Variables in 1970 (Terminal Equations Are Those With Multiple Correlation, R, Approximating .90)

Step No.	Variable entered	Oreg. R	Variable entered	N.Dak. R	Variable entered	Minn. R
1	Minn. total seed yield	.7683	N. D. pod length	.8242	Minn. seeds/umbel	.8245
2	Oreg. barren flowers	.8311	N. D. vigor	.9200	Minn. vigor	.8871
3	Minn. erectness	.8963			Mo. erectness	.9288
4	Ill. height	.9274				

Table 17. — Summary of Stepwise Regression for Predicting 1970 Oregon Second-Year Seed Yield From Different North Central States With Various Independent Variables in 1970 (Terminal Equations Are Those With Multiple Correlation, R, Approximating .90)

Step No.	North Dakota	R	Minnesota	R	Illinois	R	Missouri	R
1	Total seed yield	.6363	Total seed yield	.7683	Seeds/umbel	.7190	Dry wt./plant	.5364
2	Stems/plant	.6826	Erectness	.8232	Erectness	.7895	Total seed yield ..	.6333
3	Pods/umbel	.7795	Flowers/umbel ...	.8864	Umbels/plant	.8263	Seed wt./100 seeds	.6977
4	Flowers/umbel ...	.8281	Pods/umbel	.8963	Pods/umbel	.8477	Umbels/plant	.7346
5	Maturity	.8476	Vigor	.9102	Dry wt./plant	.8740	Erectness	.7920
6	Erectness	.8751			Seed wt./100 seeds	.9000	Barren flowers	.8082
7	Pod length	.8817					Pods/umbel	.8360
8	Vigor	.8856					Maturity	.8652
9	Umbels/plant	.8879					Visual seed yield .	.8848
10	Seeds/umbel	.8891					Stems/plant	.8973
11	Dry wt./plant ...	.8891						

Table 18. — Summary of Stepwise Regression for Predicting 1970 North Dakota Second-Year Seed Yields From Different North Central States With Various Independent Variables in 1970 (Terminal Equations Are Those With Multiple Correlation, R, Approximating .90)

Step No.	North Dakota	R	Minnesota	R	Illinois	R	Missouri	R
1	Pod length	.8242	Total seed yield .	.7453	Seeds/umbel	.7267	Total seed yield ..	.4643
2	Vigor	.9200	Flowers/umbel	.8102	Pod length	.8174	Barren flowers	.5795
3			Visual seed yield	.8690	Stems/plant	.8503	Dry wt./plant	.6508
4			Stems/plant	.8782	Total seed yield	.8769	Umbels/plant	.6989
5			Pod length	.8907	Umbels/plant	.9126	Seed wt./100 seeds	.7679
6			Erectness	.8947			Pod length	.8051
7			Umbels/plant	.8971			Flowers/umbel	.8201
8			Height	.8997			Height	.8277
9							Pods/umbel	.8315
10							Stems/plant	.8402
11							Erectness	.8437
12							Maturity	.8464
13							Vigor	.8466
14							Visual seed yield .	.8467

SUMMARY

Thirty birdsfoot trefoil clones were selected from the breeding programs of the Agricultural Experiment Stations at Illinois (8 clones), Iowa (6 clones), Minnesota (7 clones), and Missouri (9 clones). These clones were vegetatively propagated and replicated in space-planted nurseries in Illinois, Iowa, Minnesota, North Dakota, and Oregon. The relationships among 17 plant characteristics were measured at each location, and seed yields were evaluated by correlation and regression procedures. The objectives of this study were to determine: (a) whether associations exist between seed production potential and morphological and physiological plant characteristics, and (b) if such associations are great enough to aid in selection of plants having both desirable forage and seed production potential.

Most of the morphological characteristics of these selected clones displayed very little difference between first- and second-year growth. The average number of stems per plant, umbels per plant, dry weight per plant, seeds per umbel, and total seed yield increased during the second year of growth.

Three components of seed yield (umbels per plant, flowers per umbel, and pods per umbel) measured in three seed-producing areas (Oregon, North Dakota and Minnesota) indicate that significant differences in character means were found among the clones each year and at each location.

Measured during the first year of growth, phenotypic characteristics which correlated consistently and highly with seed yields were pods per umbel, total seed yield, and seeds per umbel.

Step-wise regression analysis was used to predict seed yields in various states from the 17 plant characteristics in both first- and second-year growth. Terminal equations were established with the multiple correlation R approximating .90. Pods per umbel measured in Oregon accounted for the largest amount of variability when predicting first-year seed yields in Oregon. With the addition of stems per plant measured in North Dakota, Illinois, and Iowa, plus dry weight in Iowa, a terminal multiple correlation, R = .9039, was obtained. Three variables were needed for predicting North Dakota first-year seed yields — dry weight and pods per umbel measured in North Dakota, and pod length measured in Illinois. Six variables were needed for best predicting seed yields in Minnesota.

For clones in all states, pods per umbel was the most frequent independent variable needed for predicting first-year seed yields.

Second-year-predictive seed-yield equations were quite different from the first-year seed-yield equations. North Dakota and Minnesota seed yields were best predicted from using their own independent variables rather than by data from other states. Total seed yield was one of the more frequent variables used in predicting second-year seed yield; erectness and umbels per plant were also important.

Research also was conducted to evaluate the forage and seed yields of the O. P. progeny from these same birdsfoot trefoil clones. Tests were conducted in the North Central states in which the clones originated, and results will be published as a North Central Regional publication.

Table 19. — Summary of Stepwise Regression for Predicting 1970 Minnesota Second-Year Seed Yield From Different North Central States With Various Independent Variables in 1970 (Terminal Equations Are Those With Multiple Correlation, R, Approximating .90)

Step No.	North Dakota	R	Minnesota	R	Illinois	R	Missouri	
1	Total seed yield	.7453	Seeds/umbel	.8245	Seeds/umbel	.7044	Total seed yield	.4865
2	Umbels/plant	.7706	Vigor	.8871	Flowers/umbel	.7694	Dry wt./plant	.5980
3	Pods/plant	.8006	Pods/umbel	.9213	Maturity	.8046	Erectness	.6485
4	Dry wt./plant	.8306			Pod length	.8677	Umbels/plant	.7046
5	Maturity	.8529			Umbels/plant	.8863	Seed wt./100 seeds	.7307
6	Erectness	.8673			Stems/plant	.8984	Maturity	.7487
7	Stems/plant	.8943			Seed wt./100 seeds	.9063	Pods/umbel	.7553
8	Pod length	.8974					Stems/plant	.7737
9	Vigor	.9024					Flowers/umbel	.7853
10							Height	.8024
11							Pod length	.8092
12							Visual seed yield	.8193
13							Vigor	.8199
14							Barren flowers	.8200

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